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## (54) Balancing apparatus and method for rotor shaft flange

Auswuchtvorrichtung und -verfahren für Rotorwellenflansch

Dispositif et procédé d'équilibrage de bride pour un arbre de rotor

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(73) Proprietor: **ROLLS-ROYCE PLC**
**London, SW1E 6AT (GB)**

(72) Inventor: **Wagner, Stefan Jochen**
**Derby DE24 3LU (GB)**

(74) Representative: **Gunn, Michael Alan**
**Intellectual Property Dpt ML 9,**
**Rolls-Royce plc**
**P.O. Box 31**
**Derby DE24 8BJ (GB)**

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## Description

**[0001]** The present invention relates to anti-score plates for use in balancing and protecting a bolted rotatable flange. In particular, it relates to the use of such anti-score plates in a gas turbine engine.

**[0002]** It is common practice to use bolts and nuts to attach flanges together. A problem arises, however, if the bolt head makes direct contact with the flange surface. On tightening the bolt, the bolt head may scratch the flange surface which may ultimately lead to the cracking and breaking of the flange. It is not possible simply to put a washer between the bolt head and the flange surface because on tightening the bolt, the washer itself may rotate and damage the flange surface. The problem has therefore been addressed by using an anti-score plate instead of a washer. Instead of having a single hole for receiving a single bolt, an anti-score plate has a plurality of holes each of which receives a bolt. Therefore the anti-score plate does not rotate on tightening the bolts.

**[0003]** It is common practice to use flanges to connect rotating shafts. The flange of one rotating shaft is bolted to the flange of the other rotating shaft. A problem, however, arises if the connected shafts are rotating at reasonably high speeds. The flanges may introduce off-axis inertia which if not balanced, will impede the smooth rotation of the connected shafts. This problem has been addressed in the prior art by using balance weights attached to the flange or using anti-score plates which have balance weights attached to balance the rotating shaft. US 3916495, which describes a method and means for balancing a gas turbine for field replacement, attaches weighted washers to a tie bolt. The tie bolt does not transmit torque and serves to maintain a turbine rotor disk in spaced axial relation with a shaft. Fig. 1 illustrates a prior art balanced bolted flange. A flange 2 is bolted using a plurality of bolts 4. An anti-score plate 6 protects the surface of the flange 2 from the heads of the bolts 4. The anti-score plates 6 are identical and have digit-like extensions 8. Each of the digit-like extensions 8 has a hole 10 at its extremity. Balance weights of different masses may be attached via the holes 10. Typically, a balance weight comprises a screw, nut and washer(s) assembly. If more mass is required at a particular position, then the assembly carries more washers or heavier washers.

**[0004]** There are several drawbacks to this solution. A large number of individual balancing weights are required to balance the rotatable flange and the balanced rotatable shaft is therefore heavy. There is a limitation to the maximum mass a balance weight can have and it is often not possible to position the appropriate balancing mass at the appropriate position.

**[0005]** Thus the prior art provides an arrangement comprising:

a flange of a rotatable shaft, comprising a plurality of apertures;

a multiplicity of anti-score plates each having two or more openings aligned with corresponding apertures of the flange; and

a plurality of bolts extending through the plurality of apertures in the flange and the corresponding openings in the anti-score plates wherein each of the anti-score plates is the same.

**[0006]** The present invention is characterised in that the multiplicity of anti-score plates includes at least a first anti-score plate having a first mass and at least a second different anti-score plate having a second different mass.

**[0007]** According to one aspect of the present invention there is provided an arrangement as claimed in claim 1.

**[0008]** According to another aspect of the present invention there is provided a set of anti-score plates for use with a bolted rotatable flange as claimed in claim 6.

**[0009]** According to another aspect of the present invention there is provided a method of attaching a first shaft to a second shaft for substantially balanced rotation as claimed in claim 7.

**[0010]** Embodiments of the present invention therefore allow the use of different anti-score plates having different masses. Consequently, more balance weight can be concentrated at an optimum position by using a heavier anti-score plate. Thus, embodiments of the present invention provide greater balancing capability. In addition, the balanced rotatable shaft will be lighter.

**[0011]** The anti-score plates are preferably of the same thickness but have different shape. Using plates of the same thickness means that bolts of standard size may be used for all anti-score plates regardless of their mass.

**[0012]** For a better understanding of the present invention reference will now be made, by way of example only, to the accompanying drawings in which:-

Fig. 1 illustrates prior art anti-score plates;
Fig. 2 illustrates a gas turbine engine;
Fig. 3 illustrates an arrangement of turbine shafts;
Fig. 4 illustrates a balanced bolted flange according to a first embodiment;
Fig. 5 illustrates a balanced bolted flange according to a second embodiment; and
Figs. 6A, 6B and 6C illustrate fine balance adjusters.

**[0013]** Fig. 2 illustrates a gas turbine engine 100 comprising, in axial flow series, an air intake 111, a propulsive fan 112, an intermediate pressure compressor 113, a high pressure compressor 114, a combustor 115, a turbine arrangement comprising a high pressure turbine 116, an intermediate pressure turbine 117 and a low pressure turbine 118, and an exhaust nozzle 119.

**[0014]** The gas turbine 100 operates in a conventional

manner so that air entering the intake 111 is accelerated by the fan 112 which produces two air flows: a first air flow into the intermediate pressure compressor 113 and a second air flow which provides propulsive thrust. The intermediate pressure compressor 113 compresses the air flow directed into it before delivering that air to the high pressure compressor 114 where further compression takes place.

**[0015]** The compressed air exhausted from the high pressure compressor 114 is directed into the combustor 115 where it is mixed with fuel and the mixture combusted. The resultant hot combustion products then expand through and thereby drive the high, intermediate and low pressure turbines 116, 117 and 118, before being exhausted through the nozzle 119 to provide additional propulsive thrust. The high, intermediate and low pressure turbines 116, 117 and 118 respectively drive via high speed shaft 120, intermediate speed shaft 121 and low speed shaft 122, the high pressure compressors 114, the intermediate pressure compressors 113 and the fan 112. The high speed shaft 120 rotates at approximately 12,000 rpm and the intermediate speed shaft rotates at approximately 8,000 rpm.

**[0016]** Fig. 3 illustrates the high speed shaft 120, the intermediate speed shaft 121 and the low speed shaft 122. The shafts are coaxial with the low speed shaft 122 being positioned inside the intermediate speed shaft 121. The intermediate speed shaft 121 is positioned inside the high speed shaft 120. The high speed shaft 120 comprises a first shaft 120a and a second shaft 120b connected via bolted flanges 2. The intermediate speed shaft 121 comprises a first intermediate speed shaft 121a and a second intermediate speed shaft 121b connected via bolted flanges 2. The flanges are connected together using bolts and nuts. Anti-score plates are positioned between the heads of the bolts and the surface of the flange or between the nuts and the surface of the flange.

**[0017]** Fig. 4 illustrates a bolted flange according to one embodiment of the present invention. The view presented in Fig. 4 is of the flange 2 of the first high speed shaft 120a when observed from direction A in Fig. 3. The flange 2 is annular has a plurality of apertures (not shown) evenly spaced a radius R1. Each of the apertures receives a bolt 4. The head of the bolts is illustrated in the figure. Each of the bolts 4 passes through the flange 2, through the adjacent flange 2 of the second high speed shaft 120b and is secured in place using a nut. An anti-score plate 6a, 6b is positioned between the head of each of the bolts 4 and the surface of the flange 2. In this embodiment, the anti-score plates each receive two bolts. There are two different types of anti-score plates which are of the same thickness but different shape. A first type of anti-score plate 6a has a first mass and a second type of anti-score plate 6b has a second mass, less than the first mass. In this embodiment, twenty bolts 4, three first anti-score plates 6a and seven second anti-score plates 6b are used. The arrangement of the first anti-score plates 6a and the second anti-score plates 6b is such that the high speed shaft 120 is balanced for rotation.

**[0018]** Fig. 5 illustrates a modification to the embodiment of Fig. 4. The flange 2 again has twenty bolts 4, three first anti-score plates 6a and seven second anti-score plates 6b. The flange 2 is annular and the apertures for the bolts 4 lie on a circle of radius R1. The arrangement in addition, has fine balance adjusters 12. There are twenty fine balance adjusters 12. They are positioned on a circle of radius R2 (R2 less than R1). A fine balance adjuster 12 is positioned between each of the bolts 4 of each of the anti-score plates and a fine balance adjuster is positioned between each of the anti-score plates. The fine balance adjuster 12 is illustrated in more detail in each of Figs. 6a, 6b and 6c. There is a hole in each of the flanges 2 of the first high speed shaft 120a and the second high speed shaft 120b. The holes in the flanges are aligned and a screw 14 extends through the hole and is held in place by a nut 16. One or more washers 18 are positioned between the nut 16 and the flange 2. The number and shape of the washers 18 used can be varied to adjust the mass at a specific point of the flange. Thus in Fig. 6a there is illustrated two washers 18 of the same size and shape, in Fig. 6b there is illustrated two washers 18 of different size and shape and in Fig. 6c there is illustrated a washer 18 of a particular shape. The higher the rotational speed of the shaft carrying the flange 2, the greater the requirement for fine balancing of the shaft using the fine balance adjusters 12.

## Claims

1. An arrangement comprising:

   a flange (2) of a rotatable shaft (120a), comprising a plurality of apertures;
   a multiplicity of anti-score plates (6a,6b) each having two or more openings aligned with corresponding apertures of the flange;
   a plurality of bolts (4) extending through the plurality of apertures in the flange (2) and the corresponding openings of the anti-score plates (6a,6b), **characterised in that**, the multiplicity of anti-score plates (6a,6b) comprises at least a first anti-score plate (6c) having a first mass and at least a second different anti-score plate (6b) having a second, different, mass.

2. An arrangement as claimed in claim 1, **characterised in that** the first anti-score plate (6a) and the second anti-score plate (6b) have the same thickness.

3. An arrangement as claimed in claim 1 or 2, **characterised in that** the multiplicity of anti-score plates

(6a,6b) are arranged so that the rotatable flange (2) is substantially balanced.

4. An arrangement as claimed in claim 3, **characterised in that** said arrangement further comprises fine balance adjustment means (12).

5. A gas turbine engine comprising an arrangement as claimed in any preceding claim for connecting turbine shafts of the gas turbine engine.

6. A set of anti-score plates (6a,6b) for use with a bolted rotatable flange (2) **characterised in that** said plates (6a,6b) comprises: at least a first anti-score plate (6a) having a first mass and at least a second different anti-score plate (6b) having a second, different, mass.

7. A method of attaching a first shaft (120a) to a second shaft (120b) for substantially balanced rotation **characterised in that** said method comprises the steps of:

bolting a flange (2) of a first shaft (120a) to a flange (2) of a second shaft (120b);
protecting the surface of one of the flanges (2) from each bolt (4) by placing an anti-score plate (6a,6b) between each bolt (4) and the flange (2), **characterised by**: selecting and placing at least one first anti-score plate (6a) having a first mass and selecting and placing at least one second anti-score plate (6b) having a second mass.

**Patentansprüche**

1. Anordnung mit den folgenden Merkmalen:

einem Flansch (2) einer drehbaren Welle (120a), der eine Mehrzahl von Löchern aufweist;

eine Mehrzahl von Kratzschutzplatten (6a, 6b), von denen jede zwei oder mehrere Löcher aufweist, die auf die entsprechenden Löcher des Flansches ausgerichtet sind;

eine Mehrzahl von Bolzen (4), die durch die Mehrzahl von Löchern im Flansch (2) und die entsprechenden Löcher in den Kratzschutzplatten (6a, 6b) geführt sind,

**dadurch gekennzeichnet, dass** die Mehrzahl der Kratzschutzplatten (6a, 6b) wenigstens eine erste Kratzschutzplatte (6a) mit einer ersten Masse und wenigstens eine zweite unterschiedliche Kratzschutzplatte (6b) aufweist, die eine zweite unterschiedliche Masse besitzt.

2. Anordnung nach Anspruch 1, **dadurch gekennzeichnet, dass** die erste Kratzschutzplatte (6a) und die zweite Kratzschutzplatte (6b) die gleiche Dicke besitzen.

3. Anordnung nach den Ansprüchen 1 oder 2, **dadurch gekennzeichnet, dass** die Mehrzahl der Kratzschutzplatten (6a, 6b) derart angeordnet ist, dass der rotierende Flansch (2) im Wesentlichen ausgewuchtet ist.

4. Anordnung nach Anspruch 3, **dadurch gekennzeichnet, dass** die Anordnung außerdem Feinauswuchtmittel (12) aufweist.

5. Gasturbinentriebwerk mit einer Anordnung nach einem der vorhergehenden Ansprüche zur Verbindung von Turbinenwellen eines Gasturbinentriebwerks.

6. Eine Gruppe von Kratzschutzplatten (6a, 6b) zur Benutzung in Verbindung mit einem verbolzten drehbaren Flansch (2), **dadurch gekennzeichnet, dass** die Platten (6a, 6b) folgende Teile umfassen: wenigstens eine erste Kratzschutzplatte (6a) mit einer ersten Masse und wenigstens eine zweite unterschiedliche Kratzschutzplatte (6b) mit einer zweiten unterschiedlichen Masse.

7. Verfahren zur Festlegung einer ersten Welle (120a) an einer zweiten Welle (120b) in einem im Wesentlichen ausgewuchteten Rotationszustand, **dadurch gekennzeichnet, dass** das Verfahren die folgenden Schritte aufweist:

es wird ein Flansch (2) einer ersten Welle (120a) an einem Flansch (2) einer zweiten Welle (120b) verbolzt;

es wird die Oberfläche eines der Flansche (2) gegen jeden Bolzen (4) geschützt, indem eine Kratzschutzplatte (6a, 6b) zwischen jeden Bolzen (4) und den Flansch (2) gefügt wird,

**dadurch gekennzeichnet, dass** wenigstens eine erste Kratzschutzplatte (6a) mit einer ersten Masse ausgewählt und plaziert wird und dass wenigstens eine zweite Kratzschutzplatte (6b) ausgewählt und plaziert wird, die eine zweite Masse besitzt.

**Revendications**

1. Arrangement comprenant :

une bride (2) d'un arbre rotatif (120a), comprenant une pluralité d'ouvertures ;
une multiplicité de plaques anti-éraflures (6a, 6b) chacune présentant deux ou plusieurs ouvertures alignées avec les ouvertures correspondantes de la bride;
une pluralité de boulons (4) s'étendant à travers la pluralité d'ouvertures dans la bride (2) et les ouvertures correspondantes des plaques anti-éraflures (6a, 6b,), **caractérisé en ce que**, la multiplicité de plaques anti-éraflure (6a, 6b) comprend au moins une première plaque anti-éraflures (6c) présentant une première masse et au moins une seconde plaque anti-éraflures différente (6b) présentant une seconde masse différente.

2. Arrangement selon la revendication 1, **caractérisé en ce que** la première plaque anti-éraflures (6a) et la seconde plaque anti-éraflures (6b) présentent la même épaisseur.

3. Arrangement selon la revendication 1 ou 2, **caractérisé en ce que** la multiplicité de plaques anti-éraflures (6a, 6b) sont disposées de telle sorte que la bride rotative (2) est sensiblement équilibrée.

4. Arrangement selon la revendication 3, **caractérisé en ce que** ledit arrangement comprend en outre des moyens d'ajustement d'équilibre fins (12).

5. Moteur à turbine à gaz comprenant un arrangement selon l'une quelconque des revendications précédentes pour connecter les arbres de turbines du moteur à turbine à gaz.

6. Jeu de plaques anti-éraflures (6a, 6b) destiné à être utilisé avec une bride rotative boulonnée (2) **caractérisé en ce que** lesdites plaques (6a, 6b) comprennent : au moins une première plaque anti-éraflures (6a) présentant une première masse et au moins une seconde plaque anti-éraflures différente (6b) présentant une seconde masse différente.

7. Procédé pour attacher un premier arbre (120a) à une second arbre (120b) pour une rotation sensiblement équilibrée **caractérisé en ce que** ledit procédé comprend les étapes de :

boulonner une bride (2) d'un premier arbre (120a) à une bride (2) d'un second arbre (120b);
protéger la surface d'une des brides (2) de chaque boulon (4) en plaçant une plaque anti-éraflures (6a, 6b) entre chaque boulon (4) et la bride (2), **caractérisé par** le choix et le positionnement d'au moins une première plaque anti-éraflure (6a) présentant une première masse et le choix et le positionnement d'au moins une seconde plaque anti-éraflures (6b) présentant une seconde masse.

Fig.1.

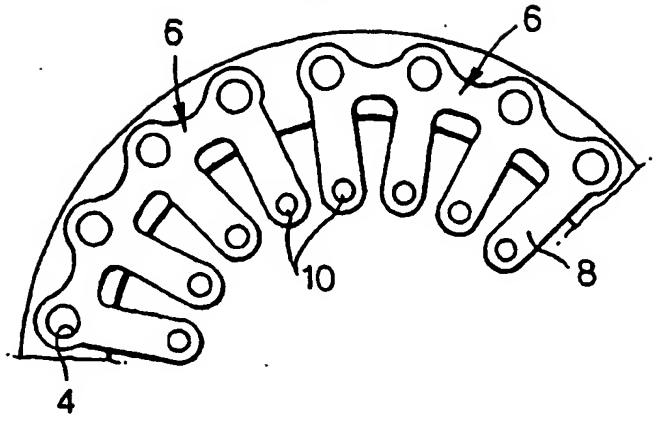


Fig.2.

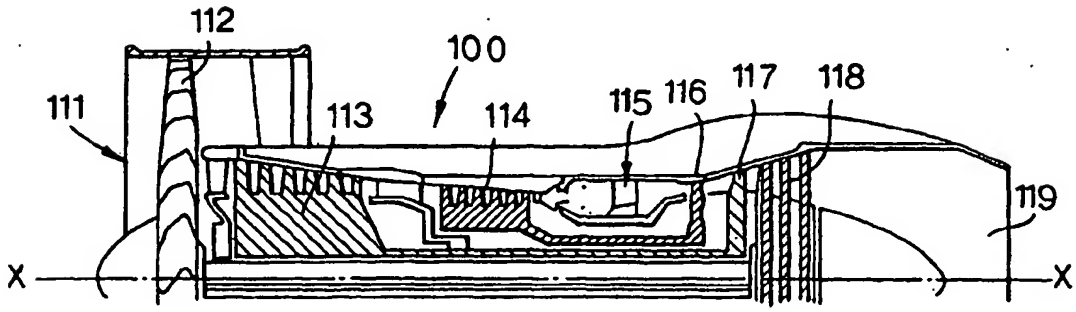


Fig.3.

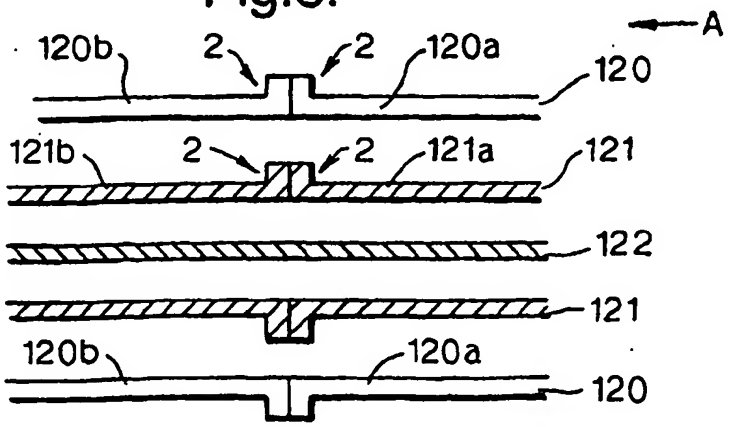

Fig.4.

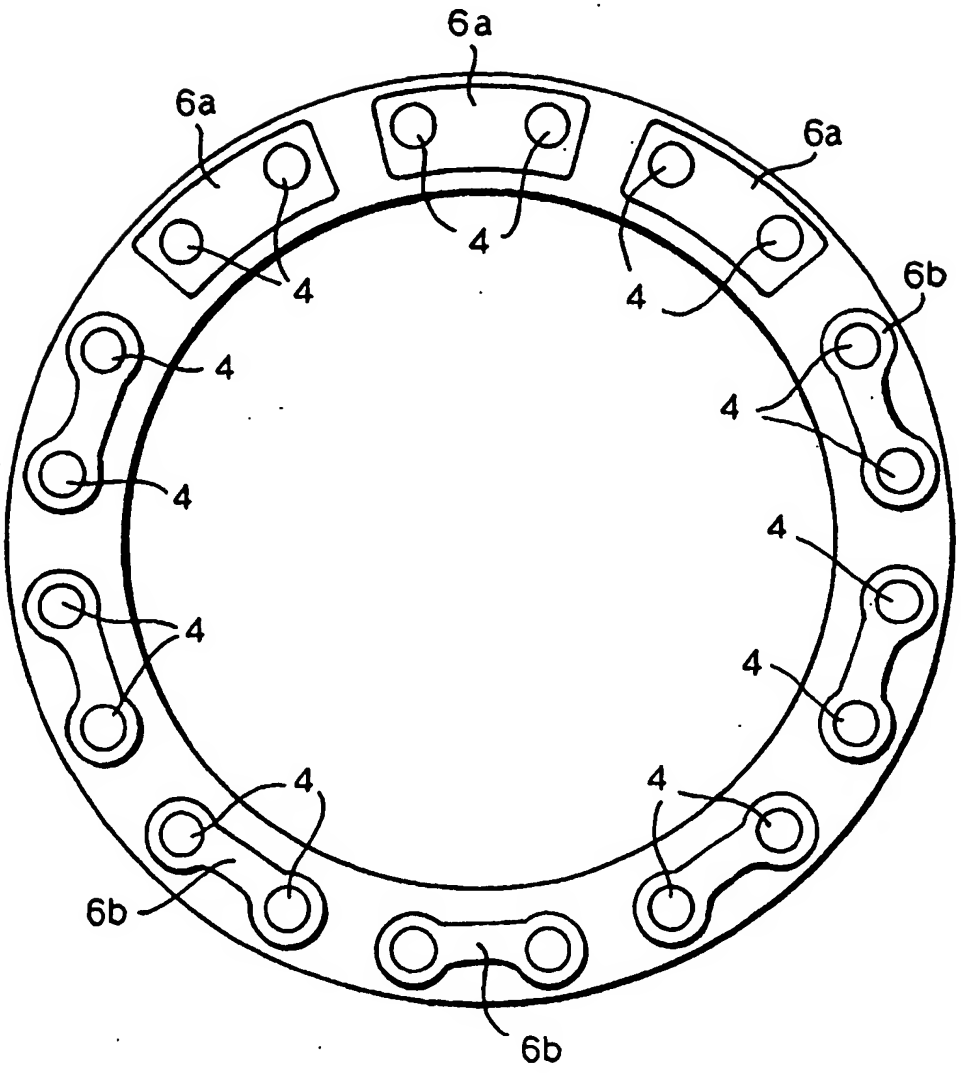

Fig.5.

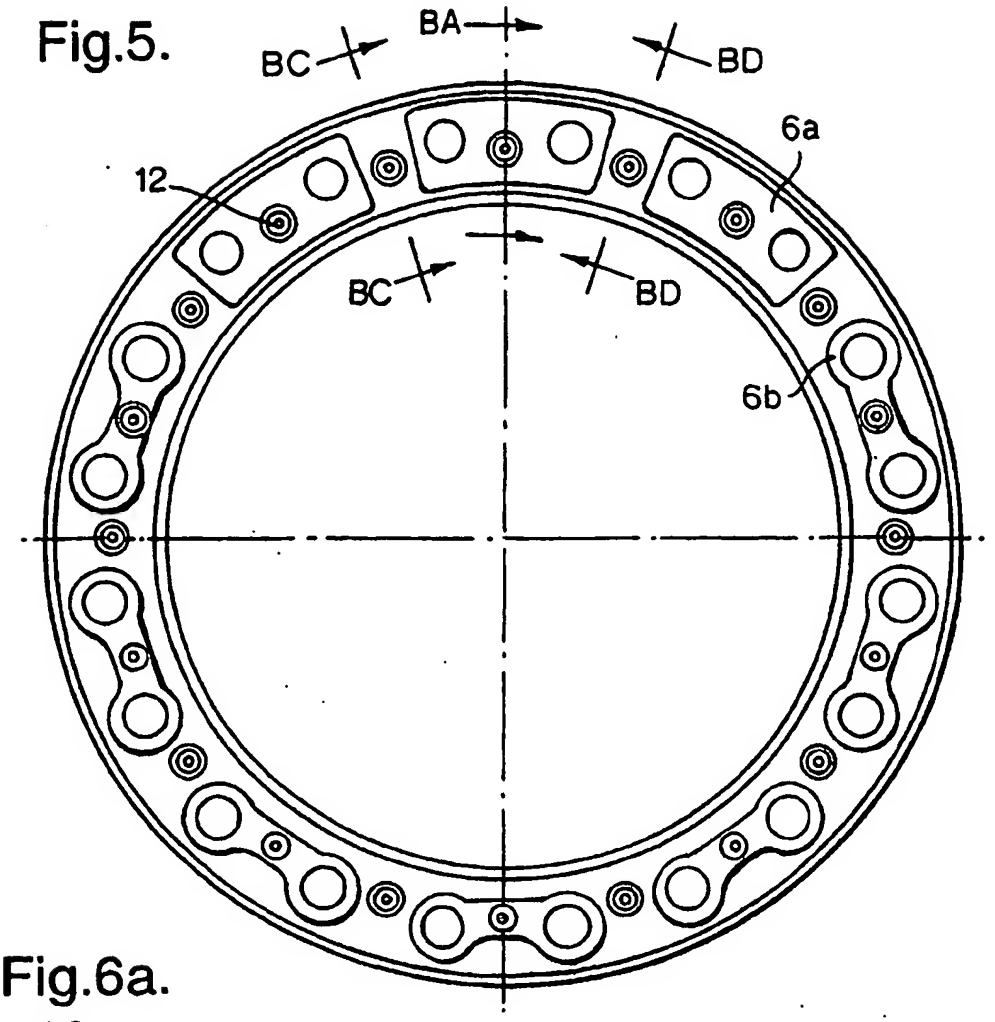


Fig.6a.

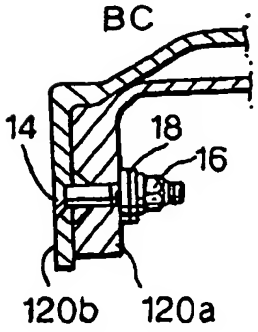


Fig.6b.

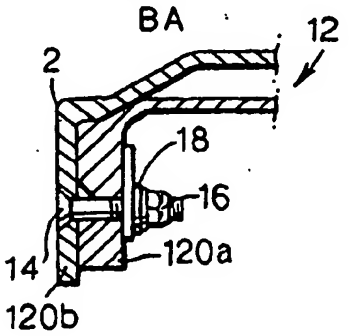


Fig.6c.